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Ultrasound for human spine

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acquired on the same day with patient repositioning. Each exam consisted of one low resolution scan ($0.313 \times 0.313 \times 0.5$ mm^3 and ~3 min scan time), and one high resolution scan ($0.156 \times 0.156 \times 0.5$ mm^3 and ~16 min scan time). The prospective registration utilized a MI rigid registration algorithm (ITK) to determine the translation and rotation required to scan the follow-up image aligned to the baseline image. Multi-scale MI rigid registration with a conjugate gradient descent optimizer, three levels, and a nearest neighbour interpolator was then applied off-line retrospectively to register the normal follow-up images to their corresponding baselines. The normal high resolution follow-up images were also manually registered to the baselines by visually matching corresponding slices. A volume of interest (VOI) which included only trabecular bone and bone marrow, consisted of twenty axial slices and was manually defined using a graphics cursor on a slice by slice basis. Previously established methods were then used to compute the apparent trabecular bone structural parameters: App.BV/TV, App.Tb.Sp., App.Tb.Th., and App.Tb.N. Data was compared and analyzed using repeated measures of analysis of variance and the Bonferroni *t* test.

3. Results

Follow-up trabecular bone parameters were not significantly different ($p > 0.05$) from baseline when determined from prospectively, multi-scale retrospectively, or manual retrospectively registered images. Difference between the prospective registration output and the multi-scale retrospective registration were within the resolution of slice thickness (0.5 mm) for translation and within one degree for rotation.

4. Conclusion

The study of the progression of bone diseases or the efficacy of a treatment based on MRI requires the proper analysis of corresponding regions of interest in the baseline and follow-up scans. In this work, we have confirmed the feasibility of using a MI based method which requires no segmentation to prospectively register or retrospectively register longitudinal MR images of the tibia. The advantage of prospective registration is that alignment can be ensured on-line, just prior to scanning the patient.

The ellipsoidal harmonic representation of 3D shapes

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Keywords Spherical harmonic transform · Ellipsoidal harmonic representation · Shape analysis

1. Introduction

Statistical shape analysis of 3D anatomical structures is a powerful tool to quantitatively locate pathological changes. Spherical harmonic (SPHARM) description is commonly used to represent anatomical surfaces. Mathematically, the spherical harmonics are the angular portion of orthogonal solutions to the Laplace equation in the spherical coordinate system. However, for human organs that do not have near-spherical boundaries (actually, most human organs do not have spherical appearance), using spherical harmonic to model these structures with a certain precision requirement may involve a high degree of expansion, which is less effective and efficient.

2. Methods

We propose to use the ellipsoidal harmonic (ELPHARM) expansion instead of the spherical one to approximate anatomical surfaces. To represent non-spherical shapes like the lateral ventricle in human brain, ELPHARM requires a smaller degree of expansion than SPHARM to approximate the structure with the same requirement on the accuracy. Actually, the ELPHARM generalizes the traditional SPHARM since the ellipsoid components can degenerate to the sphere ones.

3. Results

The ELPHARM is applied to represent the brain structures with various morphologies. The first data we used is the lateral ventricle surface segmented from brain MRI volumetric data. We derived an ellipsoidal harmonic expansion of degree 7 of the lateral ventricle using the ELPHARM modelling, while the spherical harmonic expansion degree in the SPHARM modelling is as high as 16 to achieve the same approximation accuracy (i.e. the mean square distance is around 0.1). These experiments also demonstrate the strong potential of ELPHARM to smoothly represent a shape and to compress the information carried by the seemingly complex surface structures.

4. Conclusion

Theoretically, the introduction of ellipsoidal harmonics greatly reduces the volume of possible divergence in SPHARM. In statistical morphometry problems, ELPHARM can be used to accurately and efficiently represent the anatomical surfaces to a certain degree of details for population comparison and shape compression.

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Ultrasound for human spine: vertebral features enhancement using length attribute filter

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Keywords Length attribute filter · Vertebral features

1. Introduction

In an attempt to image the human spine of a volunteer, an ultrasound volume was obtained. In the volume, the vertebral parts should have higher intensity than the surrounding tissues since these parts, as other bony structures, have high sound impedance. However, muscles and other parts give echoes of the same strength. By enhancing the vertebral parts, the localization of these parts can be done easier. Such an enhancement method should consider the non-smoothness of ultrasound images. It is caused by the nature of ultrasound images and the results of the interpolation process of empty parts. The empty parts represented the parts that were not scanned which usually are present in the image using a freehand 3D ultrasound system. This paper describes the work to enhance the vertebral parts that appeared in ultrasound images using a so-called length attribute filter.

2. Methods

The volume was represented as *max-tree*, a tree representation of a 3D grey level image based on the intensity and voxels connectivity or spatial relationship. Each node of the max-tree stores a 3D region and its longitudinal length. Vertebral parts and non-vertebral parts (muscles and skin) were expected to be separable and to have a different length in longitudinal direction. The non-vertebral parts form elongated structures while the vertebral parts are shorter in this direction. The enhancement was done to the max-tree by inspecting all nodes and comparing their attribute (longitudinal length) with the length threshold range. The nodes which had a longitudinal length within the range were preserved. Otherwise, the nodes were deleted.

3. Results

The small structures and the elongated parts were filtered away from the ultrasound volume. As a result, the vertebral parts were enhanced. Quantitative evaluation delivered that the range of 6–11 mm was the optimal range of the length threshold.

4. Conclusion

Enhancing the bony parts, especially the vertebral parts in a 3D ultrasound image of human spine can be performed using a length-attribute filter. The elongated parts in the longitudinal direction such as skin and muscles can be removed by the length attribute filter. The results of the enhancement procedure make it easier to localise vertebral features.

Unsupervised clustering for shape analysis of 2D low attenuation area (LAA) of lung

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Keywords Unsupervised clustering · Fuzzy · Shape feature · Low attenuation area (LAA) · Lung

1. Introduction

The study was conducted to find number of type of similar clusters, which may mean steps of COPD, using unsupervised Fuzzy C-means clustering and 2D low attenuation area (LAA) analysis for the differentiation among obstructive lung diseases based on the features from shape analysis using High Resolution Computerized Tomography (HRCT) images. For a correct diagnosis and treatment, it is important to know patient's current state. Therefore, there were many researches to prove about generation and progress of COPD. There, however, is not much that is known about COPD. To find out the progress step of COPD, we used unsupervised fuzzy c-means clustering with lung LAA which is extracted by watershed method.

2. Methods

The images were selected from HRCT obtained in 17 healthy subjects (NL, $n = 66$), 26 patients with bronchiolitis obliterans (BO, $n = 69$), 28 patients with mild centrilobular emphysema (CLE, $n = 64$), and 21 patients with panlobular emphysema or severe centrilobular emphysema (PLE, $n = 62$). Every 265 ROIs were selected just one at each half lung for avoidance of the redundancy of images.

We used Fuzzy c-Means Algorithm for the unsupervised clustering. It minimizes the following objective function with respect to fuzzy membership and cluster centroid. For the evaluation of unsupervised clustering, Xie and Beni's (XB) index was used. XB index quantify the ratio of the total variation within clusters and the separation of clusters

3. Results

The progress step of COPD with lung LAA was evaluated by XB index, used for determination of the number of cluster. From this analysis, the number of cluster (means steps of COPD) is seven. The determined cluster number was used for clustering new HRCT images. From the clustering results, we made LAA clustered color mapping image.

4. Conclusion

In this study, we presented a new method for identifying steps of COPD through unsupervised learning and generating LAA clustered color mapped image. By the ROIs classified in consensus by two thoracic radiologists, we examined these LAA clustered results. As a result, the LAAs on ROI of different class are displayed on different color, which means that this unsupervised classification scheme conform to the clinical knowledge and characteristics of the progress of COPD.

Surface based 3D modeling of neurovascular compression syndromes

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Keywords Image segmentation and registration · MRI · Surface 3D models

1. Introduction

Combining information obtained from different kinds of tests, such as CT and MRI, along with using various ways of imaging within the MRI itself enable increasing the chance of diagnosis, better preoperative planning, and more precise modelling of tissues, which can be used in intra-operative navigation.

The aim of this study is to build a 3D model and spatial visualisation of mutual localisation of the vascular and nervous systems in a condition called Neurovascular Compression Syndromes (NCS).

2. Methods

Processing of MRI images starts from segmentation of vessels from SPoiled Gradient Recalled–Time Of Flight (SPGR-TOF) protocol and Fast Imaging Employing STeady-state Acquisition (FIESTA) series and nerves from FIESTA series. The segmentation algorithm is based on the region growing with two seed points. Before the segmentation a blur filter is used to remove noise. The blur is performed with the use of a filter tracking curvature flow, which to a large extent preserves the borders of regions, despite the blur.

Then, binary images of the vessels of both series are registered. Monomodal registration with mean squares metric and linear interpolation was chosen as the registration method. A rigid transformation was assumed to decrease the number of parameters during optimisation, which was performed with the use of the method based on the regular step gradient descent algorithm. Transformation parameters, determined in the process of registration, are used to compute the localisation and orientation of the nerves in the FIESTA series in relation to the set of coordinates of the vessels in the SPGR-TOF series.

Three-dimensional reconstruction of the binary images of the vessels and nerves is performed with the use of the Marching Cubes method.

3. Results

The tests were performed on image material coming from the MRI tests of seven patients suffering from NCS. Good or very good results were achieved for five of them. In two cases the